PB-215 081

THE ROLE OF MATHEMATICAL MODELS IN THE POTOMAC RIVER BASIN WATER QUALITY MANAGEMENT PROGRAM

Federal Water Pollution Control Administration
Annapolis, Maryland

December 1967

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PB 215 081

THE ROLE OF MATHEMATICAL MODELS

IN

THE POTOMAC RIVER BASIN WATER QUALITY MANAGEMENT PROGRAM

Presented December 13, 1967
at an interdepartmental conference
convened at the request of
Assistant Secretary Kenneth Holum

Hetling-Jaworski
Chesapeake Field Station
CB-SRBP
FWPCA
Middle Atlantic Region
December 1967

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GENERAL

Water quality investigations in the Potomac River Basin have been conducted for the past several years by the Chesapeake Field Station as part of the Chesapeake Bay-Susquehanna River Basins Project. A map of the Potomac River Basin showing existing and proposed reservoirs is exhibited in Figure 1.

As an integral part of the project, large mathematical simulation models were developed. The models, after verification, are being applied to this river basin as well as others in the Chesapeake Bay drainage system. The general relationship of these models to management of Potomac water quality is shown in Figure 2 and the attached outlines.

While the hydrological principles and quality formulations applied are not new, the use of these models in the application of systems analysis techniques has substantially reduced analysis time and costs, has achieved a precision commensurate with the accuracy of data input and has allowed the engineer to observe the broad spectrum of water quality parameters synoptically.

CONCLUSIONS

The series of models presented have already proved their effectiveness to water quality managers. They have been instrumental in clarifying several points in the decision making process. The problems they have solved, and some current and envisioned future applications, are stated in more detail in the attached outlines.

From the successful experience in use of mathematical models in the water quality management and control programs, the Chesapeake Field Station has observed the following:

1. The relative time and money spent on systems analysis, because of the ability to use computers, have been reduced compared to that required for planning, assembling and analyzing the necessary field data for verification.

2. Field testing and verification of the models is expensive. Over a half million dollars have been expended in collection of field data and verification of the Potomac system to bring it to its present stage of usefulness. As much again will be required to develop the refinements desirable to complete the job.

3. There remains a communications gap between water quality administrators and engineers with respect to the capabilities of mathematical models. Much more emphasis should be placed upon bridging this gap in order to realize the full potential of the models.

4. Since the nature of the planning process is dynamic and continuing and the changes in technology rapid, the models require continuous updating in order to retain their usefulness.

SUBJECT: The Potomac Estuary Water Quality Model (See Figure 3)

PURPOSE: To define the effects of environmental changes such as low flow augmentation and increased waste treatment on the estuary's water quality.

ORIGIN AND DEVELOPMENT: The basic theory was developed by Dr. Robert Thomann at New York University. The model's digital computer program was written by the Re-Entry Systems Department of the Missile and Space Division of General Electric under a series of contracts sponsored jointly by the Delaware Estuary Comprehensive Study and the Chesapeake Field Station. A specialized analog version of the program was also developed for the Chesapeake Field Station by Electronic Associates, Inc. The model has been field tested and verified by the field station.

SCOPE: The Potomac estuary model as presently verified extends from the head of tide at Chain Bridge to the mouth of the estuary at the Chesapeake Bay. It is presently capable of simulating the effects of low flow augmentation, wastewater diversions, water supply withdrawals, and increased wastewater treatment on dissolved oxygen (DO), phosphorus, chloride and bacterial concentrations in the estuary. Solutions are available for both dynamic (time dependent) and steady-state situations.

PRESENT APPLICATIONS: Up to the present time, the model has been used in the following studies.

1. Determination of a range of feasible alternative plans to improve water quality in the estuary for the Water Quality Sub-Task Force of the President's Project Potomac. From this study it was concluded that there are technologically feasible alternatives to large upstream dams for water quality control.

2. Determination for the FWPCA enforcement programs of the degree of treatment required by waste treatment plants discharging to the Potomac Estuary to meet the water quality standards adopted by the District of Columbia and the State of Maryland. The model results indicated that a high degree of advanced waste treatment is necessary.

3. Results from the model were used by Dr. Robert Davis of Resources for the Future (RFF) in his study of the effects of advances in technological software on the planning process. Dr. Davis concluded that gains from the modeling technique could be a significant advantage in the planning process.

4. The model has been used to determine the feasibility of using the upper estuary as a future emergency water supply for the Washington Metropolitan Area. On the basis of water quality, this is a feasible alternative. The economics and esthetics of such a program have not yet been investigated.

FUTURE APPLICATIONS: Continuous improvement in the accuracy and efficiency of the model will be made. The Chesapeake Field Station will use the model in developing a range of alternative water quality management programs for the Potomac River basin. This will require linkage of the upstream water quality and hydrology models. Training of state and local agencies in the application of the model has been instituted.

SUBJECT: Water Quality Simulation and Verification Model (See Figure 4)

PURPOSE: To aid in analyzing field data, establishing and verifying water quality formulation parameters, and predicting the response of the water quality in the free flowing portion of the Potomac Basin to changes in waste loadings, flow, etc.

ORIGIN AND DEVELOPMENT: Developed at the University of Michigan and field tested at the Chesapeake Field Station.

SCOPE: With predictive algorithms for biochemical oxygen demand (BOD), DO, temperature and phosphorus, the model can be used in non-tidal waters for the following:

1. Establishing and verifying the parameters of the various quality formulations;

2. Predicting the water quality in a river for a given set of environmental conditions;

3. Planning of field studies;

4. Routing of an accidental spill;

5. Verifying and editing the system for the optimal flow release model.

PRESENT APPLICATIONS: As an integral part of the field station's activities, the model has been utilized for the following:

1. Determination of wastewater treatment requirements in the North Branch of the Potomac River basin in cooperation with the State of Maryland Department of Water Resources;

2. Determination of the need for and value of reservoir storage in that portion of the basin in "Appalachia" as requested by the U. S. Corps of Engineers;

3. Investigation of the effects of wastewater treatment and flow regulation on water quality in the Patuxent River basin;

4. Analysis of field data and establishment of well-defined water quality parameters for the Monocacy River basin;

5. Determination of the times-of-travel of accidental spills as requested for the pollution surveillance program of FWPCA.

FUTURE APPLICATIONS: Continued use in verifying the quality formulation is anticipated with possible expansion as needed to better describe the system.

SUBJECT: Optimal Flow Release Model (See Figure 5)

PURPOSE: To develop optimal-release sequences from multiple reservoir systems for water supply and water quality control.

ORIGIN AND DEVELOPMENT: Developed at the University of Michigan and field tested at the Chesapeake Field Station.

SCOPE: The model with quality algorithms as described in the verification link and using dynamic programming, can be used to determine reservoir release sequences based on various optimization criteria. For a given wastewater treatment policy, release sequences can be developed to maintain the "best" quality of water for a given flow requirement with minimum reservoir storage for a given quality level. Although the model, which also includes a least-cost of reservoir storage, is limited to non-tidal waters, it can readily be linked to the Potomac Estuary Water Quality Model.

PRESENT APPLICATIONS: The model, which is still in the developmental state, has been used to determine optimal reservoir release patterns for the proposed impoundments in the Potomac Basin. Since general coefficients were used in some of the sub-basins, the results of model should be considered preliminary only.

FUTURE APPLICATIONS: After verification of the quality formulations in the entire Potomac system, the field station will be in a better position to investigate the various alternatives of water quality management, such as the relative economy of advanced waste treatment as compared to flow augmentation.

SUBJECT: Reservoir System Simulation

PURPOSE: To investigate the hydrologic performance of the existing and proposed reservoir systems in meeting given flow requirements for quality control and water supply.

ORIGIN AND DEVELOPMENT: Initially developed by the U. S. Corps of Engineers, the model was expanded by RFF and reprogrammed for the IBM 360 computer by the Chesapeake Field Station with the assistance of RFF.

SCOPE: Using either historical flows or synthetically generated traces (e.g., the synthetic hydrology model as developed by the Harvard Water Resources Group), the model can be used for the following:

1. Studying the performance of a proposed or existing reservoir system with respect to specific water supply and/or water quality flow requirements in the Washington Metropolitan Area or other critical sections of the basin;

2. Scaling reservoir systems to meet desired targets;

3. Determining the performance of a reservoir system in terms of probability of failure at a given level of performance.

PRESENT APPLICATIONS: Dr. Robert Davis of RFF has demonstrated, utilizing the data from the 1963 U. S. Army Corps of Engineers study, that there are sufficient differences in the choices of both on the matter of kinds of solutions and action to be taken in water quality management for the Potomac Estuary.

FUTURE APPLICATIONS: Once the quality formulations are verified and optimal release sequences developed, the simulation will be invaluable in investigating the consequences of the various alternative solutions to Potomac Basin water resource problems.

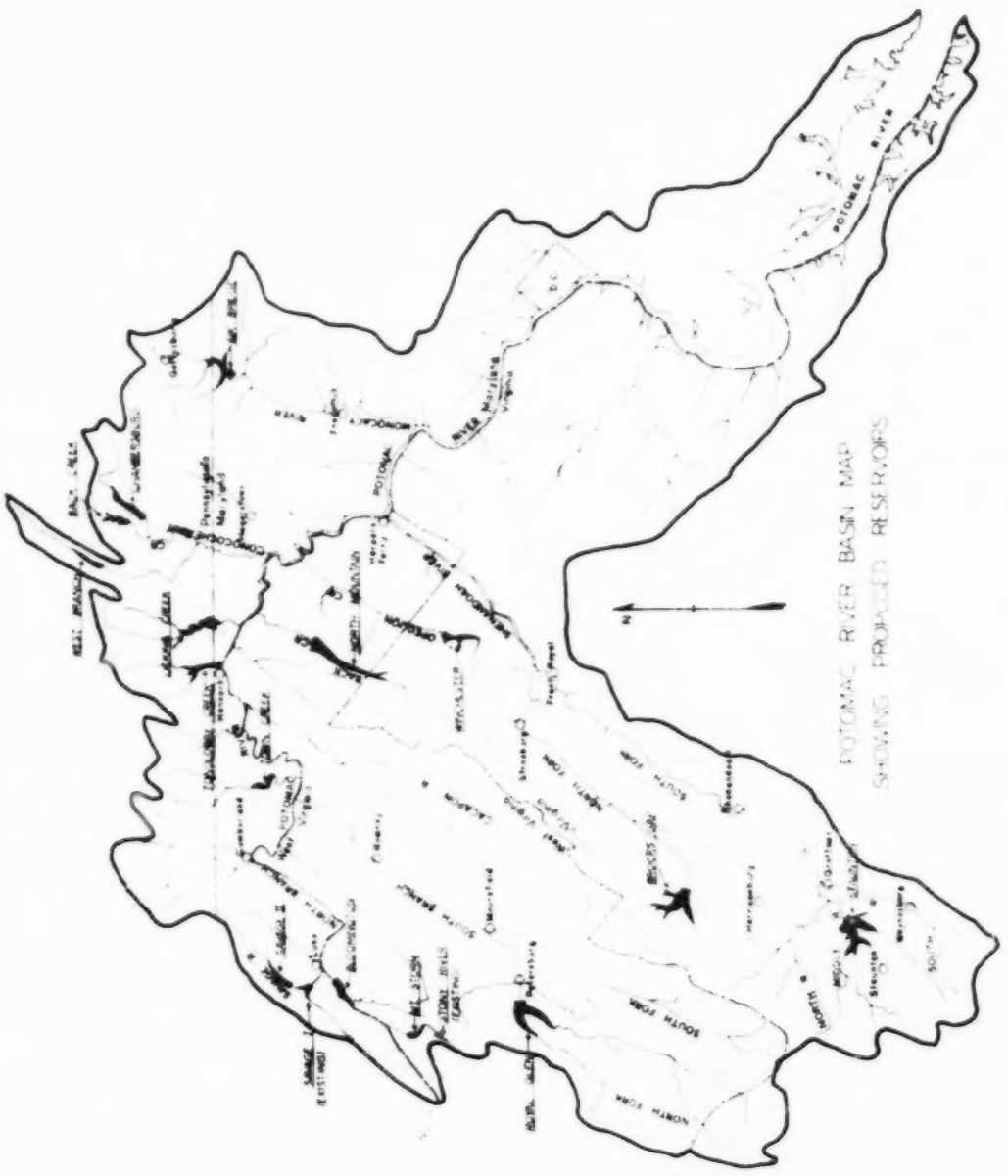
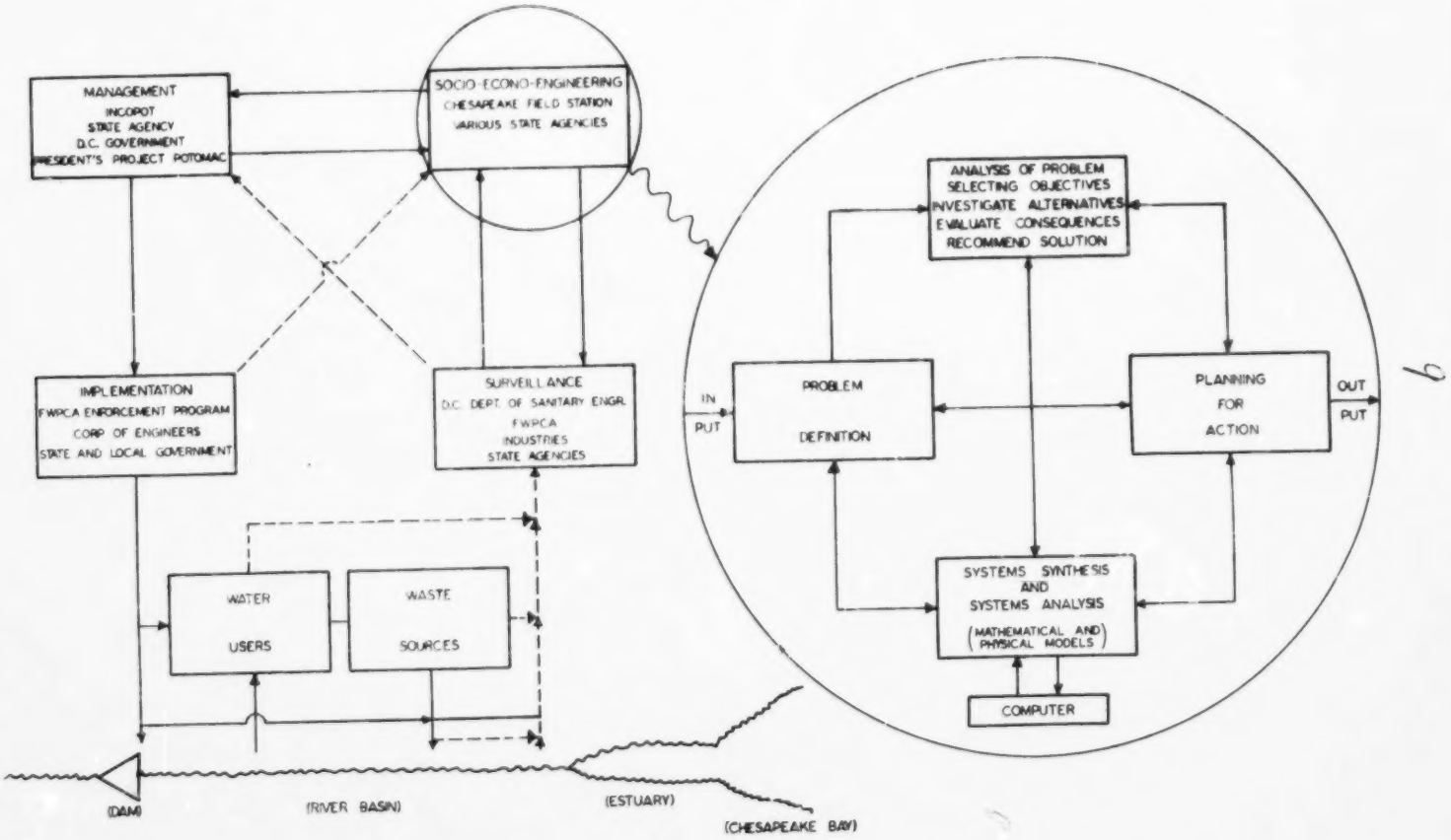
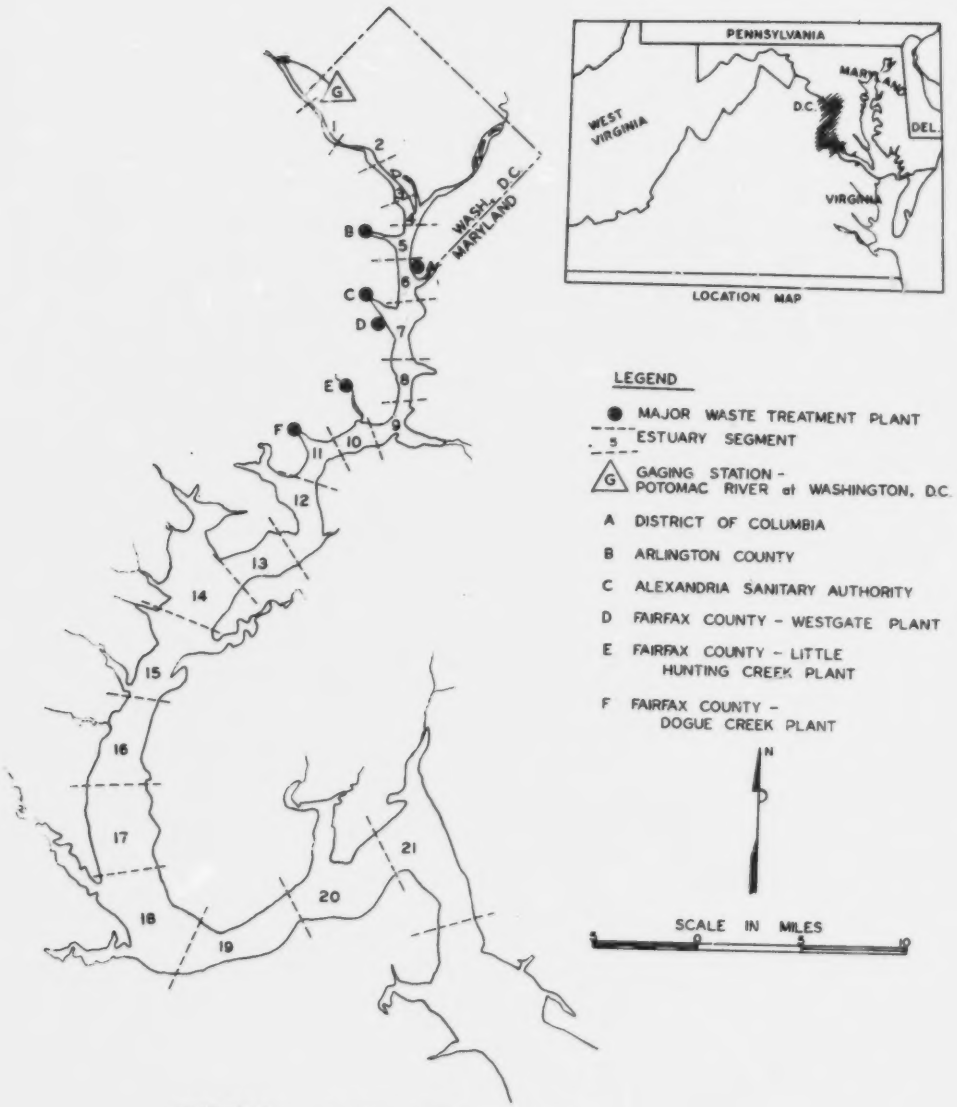

POTOMAC RIVER BASIN MAP
SHOWING PROPOSED RESERVOIRS
POTOMAC RIVER
SOUTH FORK
NORTH FORK
N

FIGURE 1



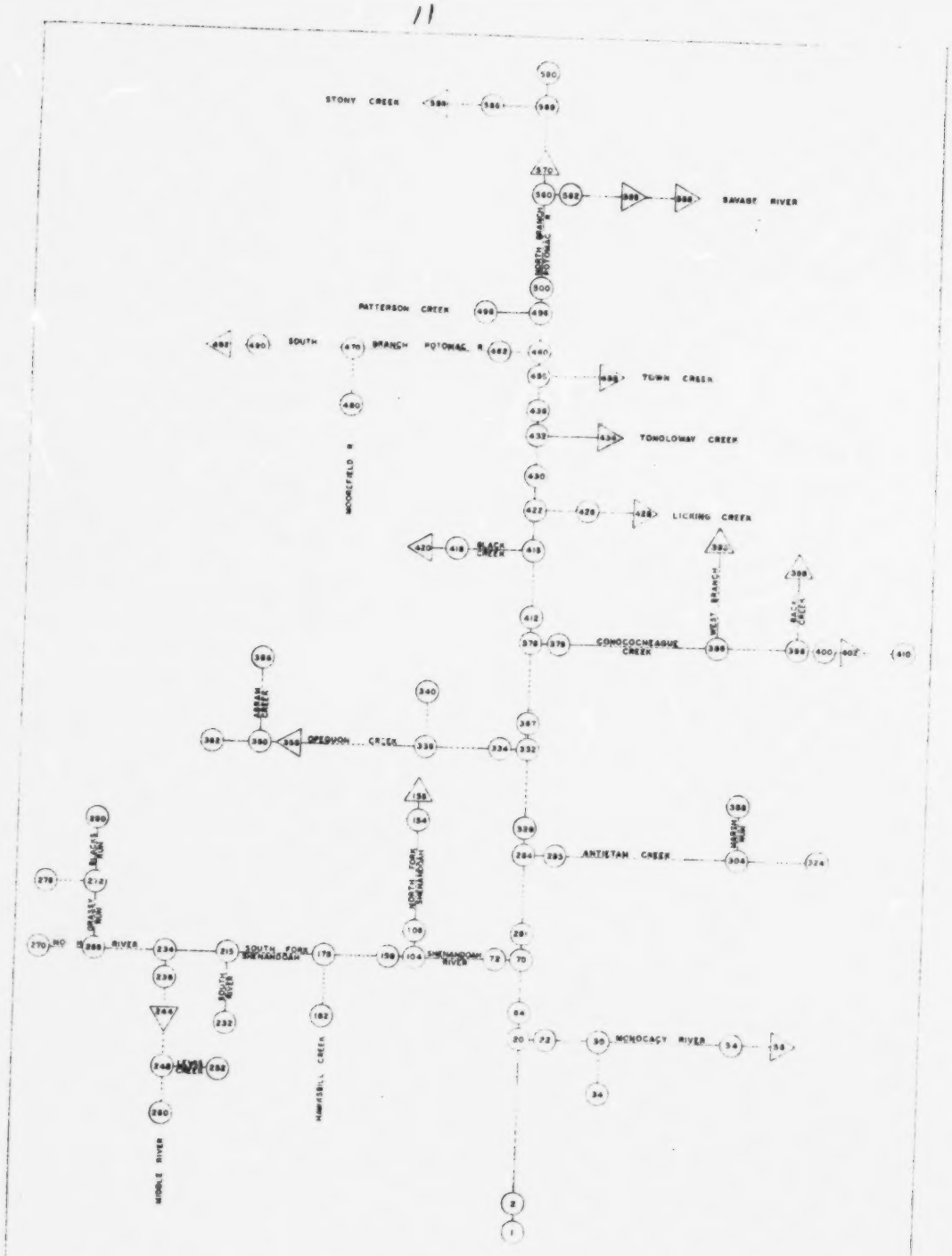
PRESENT USE OF MATHEMATICAL MODELS IN THE POTOMAC WATER QUALITY MANAGEMENT SYSTEM

FIGURE 2



POTOMAC RIVER STUDY AREA

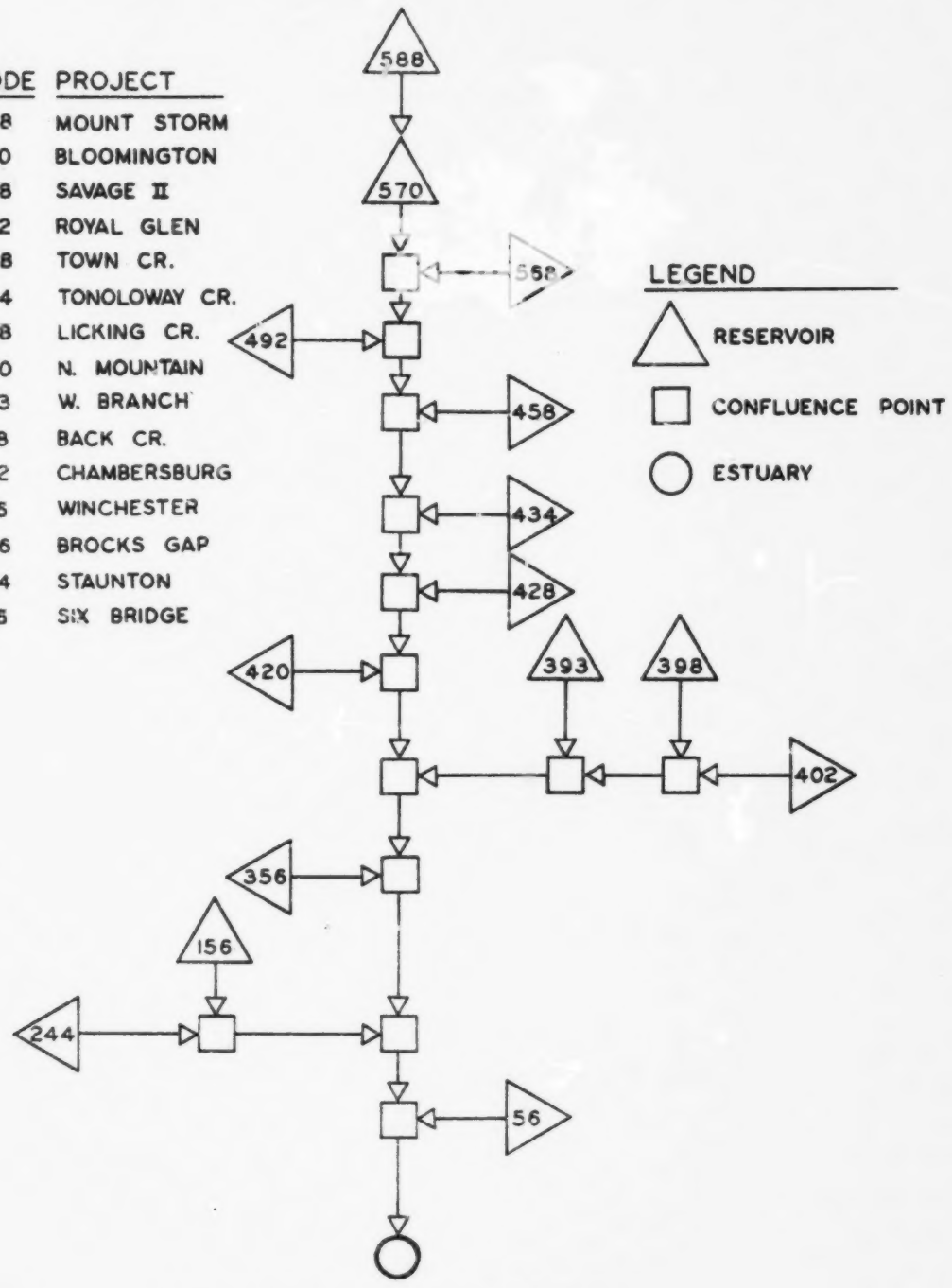
FIGURE 3



OVERALL POTOMAC RIVER BASIN SYSTEM

FIGURE 4

NODE	PROJECT
588	MOUNT STORM
570	BLOOMINGTON
568	SAVAGE II
492	ROYAL GLEN
458	TOWN CR.
434	TONOLOWAY CR.
428	LICKING CR.
420	N. MOUNTAIN
393	W. BRANCH
398	BACK CR.
402	CHAMBERSBURG
356	WINCHESTER
156	BROCKS GAP
244	STAUNTON
56	SIX BRIDGE



A SCHEMATIC REPRESENTATION
OF
PROPOSED RESERVOIR SYSTEM – POTOMAC RIVER BASIN

FIGURE 5